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# THE TIME STUDIES OF TRUCK/SHOVEL SYSTEM AT HIGHVALE MINE IN ALBERTA

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May 1985

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# THE TIME STUDIES OF TRUCK/SHOVEL SYSTEM AT HIGHVALE MINE IN ALBERTA

by

V. Srajer*

## ABSTRACT

A time study of the Highvale mine operation was under way during 1983. This report summarizes the travel times for four different types of off-highway trucks at the mine, evaluate truck performance, ton-kilometer-hour ratings for truck tires, fuel consumption, dumping and loading times, etc. The travel times are evaluated for each truck, each group of trucks and for each pit operation separately.

The data evaluated in this report will be used for validation of truck/shovel computer model, presently under development at the National Research Council in Ottawa.

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# ÉTUDES PORTANT SUR LES DURÉES DES OPÉRATIONS DU SYSTÈME DE TRANSPORT CAMION-PELLE À LA MINE HIGHVALE EN ALBERTA

par

V. Srajer*

## RÉSUMÉ

Une étude portant sur les durées des opérations à la mine de Highvale a été effectuée en 1983. Le présent rapport contient un bref exposé sur le temps de parcours de quatre différents types de camions tous terrains utilisés à la mine, présente une appréciation de la performance des camions, du rapport tonne-kilomètre-heure des pneus, de la consommation de combustibles et de la période requise pour effectuer le chargement et le déchargement, etc. Le temps de parcours de chaque camion, de chaque groupe de camions et de chaque opération minière est indiqué séparément.

Les données présentées dans ce rapport seront utilisées à des fins de validation du modèle automatisé camion-pelle que le Conseil national de recherche est présentement à mettre au point.

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# 1. INTRODUCTION

In this report, a time study of truck/shovel operation at Highvale Mine in Alberta, is summarized. This study was undertaken to obtain travel time data for the future validation of a computer model of truck/shovel operations. The truck travel times were surveyed in June, July, September and October 1983. The time was recorded at each section for various trucks used at Highvale Mine. The summary and averages were later calculated in the office using a program developed on an HP45 microcomputer.

# 2. DESCRIPTION OF TRUCK/SHOVEL SYSTEM

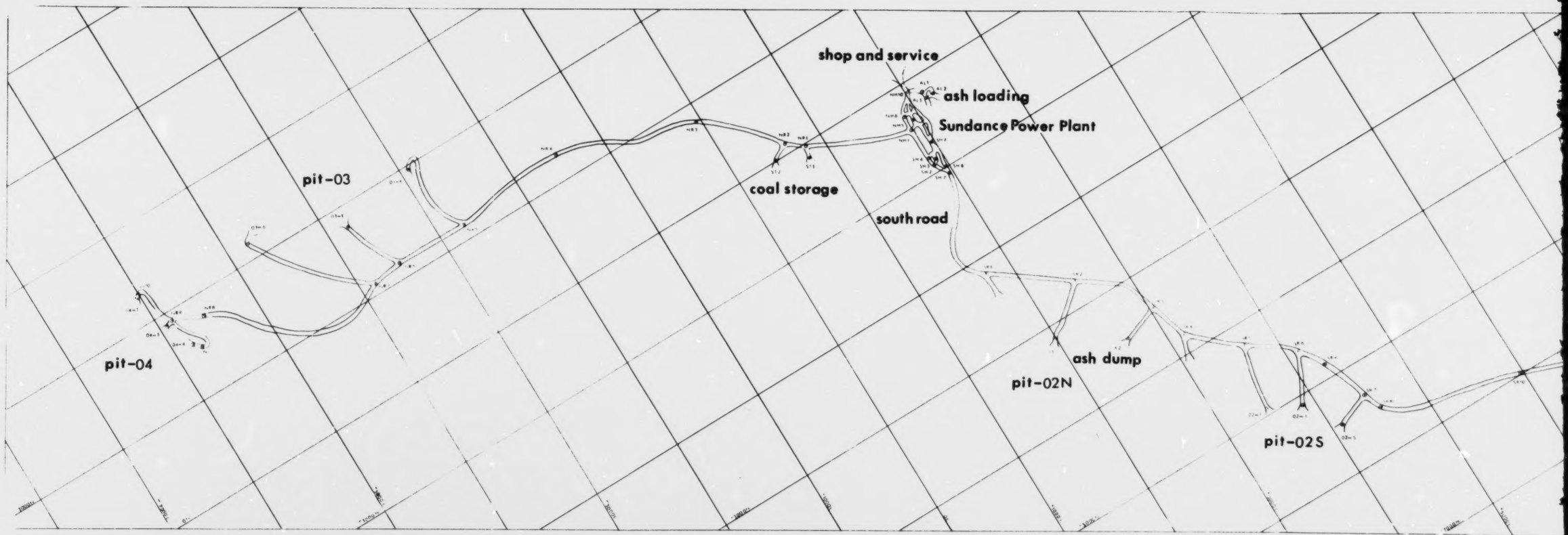
## 2.1. TRUCK TRAVEL TIMES

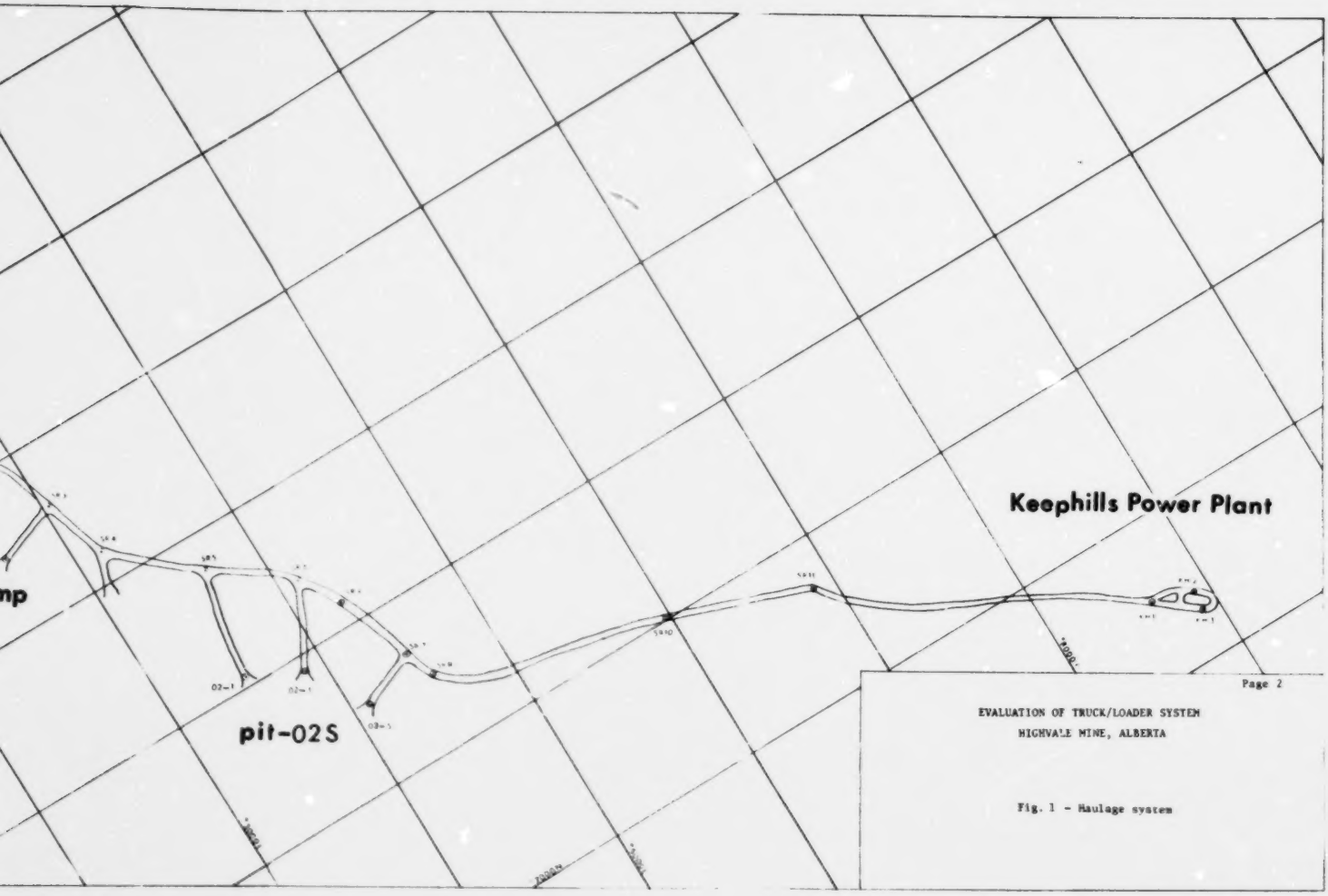
The trucks at Highvale Mine were divided into two major group: ash haulers and coal haulers. The ash haulers are Euclid R85 rear-dump trucks (4 units), the coal haulers are represented by Euclid R85 tractors (5 units), Cat 772 tractors (2 units), Terex 34-11C tractors (4 units) and Kress CH-160 trucks (3 units). Table 1 summarizes trucks used at Highvale Mine.

Only the ash trucks and coal haulers were included in this study. The end dump trucks (nos. 8126, 8127, 8225) were omitted because of their various assignments and non-productive duties (e.g. packing at stockpiles). The movement of these trucks is not considered critical for overall operation of the mine.

The Highvale Mine haulage system is shown in Fig. 1. The flow of loaded trucks from Pit 04 and 03 to MCL coal storage and the Sundance plant is generally eastward; the flow from Pit 02S is north-westward to the Sundance plant and south-eastward to the Keephills plant. The loaded ash trucks are travelling south from the ash loading site to the ash dump site in Pit 02N.

During time studies in 1983, control points were established at the side of the haulage road, primarily to identify changes in direction of the road or critical changes in the elevation (Fig. 1). The list of coordinates and elevations, as supplied by TransAlta's field survey department, are shown on Table 2. The control points on north road (from Sundance plant to Pits 3 and 4) are described as NR1 to NR11, on south road (from Sundance plant to


shop and service
ash loading
Sundance Power Plant
pit-03
coal storage
south road
pit-04
ash dump
pit-02N
pit-02S






EVALUATION OF TRUCK/LOADER SYSTEM
HIGHVALE MINE, ALBERTA

Fig. 1 - Haulage system

Table 1 - List of trucks

| Truck No. | Manufacturer | Type | Tonnage | Hauling | | |
|---|---|---|---|---|---|---|
| | | | | Ash | Coal | Partings |
| 1267 | Euclid | R85 | 77t | x | | |
| 1268 | Euclid | R85 | 77t | x | | |
| 1269 | Euclid | R85 | 77t | x | | |
| 1270 | Euclid | R85 | 77t | x | | |
| 1271 | Euclid | R85 | 91t | | x | |
| 1272 | Euclid | R85 | 91t | | x | |
| 1329 | Euclid | R85 | 91t | | x | |
| 1330 | Euclid | R85 | 91t | | x | |
| 1331 | Euclid | R85 | 91t | | x | |
| 7815 | Cat | 772 | 91t | | x | |
| 7836 | Cat | 772 | 91t | | x | |
| 8029 | Terex | 34-11C | 136t | | x | |
| 8030 | Terex | 34-11C | 136t | | x | |
| 8031 | Terex | 34-11C | 136t | | x | |
| 8032 | Terex | 34-11C | 136t | | x | |
| 8304 | Kress | CH-160 | 145t | | x | |
| 8312 | Kress | CH-160 | 145t | | x | |
| 8363 | Kress | CH-160 | 145t | | x | |
| 8126 | | | | | | x |
| 8127 | | | | | | x |
| 8225 | | | | | | x |

Pit 02S and Keephills power plant) as SR1 to SR11. The control points at Sundance plant are named NH or SH with a number, depending on their location north or south of the intersection with the north road. The points around Keephills power plant are KH1 to KH3. The control points in pits (usually bottom of the ramp) are given the same numbers as the pits. The ash loading control points are AL1 to AL3, the ash dumping points are A1 and A2. The MCL coal storage has two control points ST1 and ST2. There are additional control points in each pit that were used for in-pit time monitoring and movement of auxiliary equipment in the pit. These control points were excluded from this part of the truck/shovel study.

The sections between the individual control points, with their respective distances and differences in the elevation are summarized in Table 3.

The maximum speed at Highvale Mine is specified by management as 67 kmh for empty trucks and 60 kmh for loaded trucks.

The haulage roads are constructed on pit fill with well packed selected gravel surfacing. The haulage crest is 25 m wide, sloping from 1:25 and up to 1:40 on each side from the crest centre. The normal side slope is 1:4.

The following tables are summaries of travel times between points on the haul roads for full (F) and empty (E) coal haulers and ash trucks.

Table 4 summarizes the travel times for Euclid R85 (77T) ash haulers and for the sections between the ash loading depot and the ash dumping point in spoils of Pit 02N. The ash trucks were not observed anywhere else during our study although it is possible for the ash trucks to move to other pits of the Highvale Mine to dump waste as and when required.

Table 2 - Control point coordinates

| No. | Coordinates | | Elevation | No. | Coordinates | | Elevation |
|---|---|---|---|---|---|---|---|
| | Northing | Easting | | | Northing | Easting | |
| KH1 | -7496N | +8654E | 766.6 | NH6 | -310N | +1867E | 736.7 |
| KH2 | -7584N | +8910E | 764.0 | NH5 | -380N | +1917E | 740.0 |
| KH3 | -7698N | +8903E | 763.8 | AL1 | -178N | +2160E | 730.1 |
| SR11 | -6307N | +6858E | 745.2 | NH10 | -102N | +2030E | 732.0 |
| SR10 | -5995N | +5970E | 734.0 | AL2 | -255N | +2255E | 730.0 |
| SR8 | -5530N | +4555E | 738.5 | AL3 | -255N | +2170E | 730.0 |
| SR7 | -5345N | +4470E | 737.0 | NR1 | -29N | +810E | 734.6 |
| 02-5 | -5490N | +4110E | 725.0 | ST1 | -150N | +780E | 747.4 |
| SR9 | -4850N | +4290E | 740.0 | NR2 | +114N | +535E | 735.0 |
| SR6 | -4590N | +4135E | 728.0 | ST2 | +5N | +450E | 736.0 |
| 02-3 | -5100N | +3850E | 725.0 | NR3 | +798N | -52E | 752.2 |
| SR5 | -4240N | +3655E | 728.0 | NR4 | +1280N | -1515E | 736.5 |
| 02-1 | -4940N | +3520E | 725.0 | NR5 | +1165N | -2705E | 752.0 |
| SR4 | -3810N | +3177E | 727.7 | 03-4 | +1965N | -2800E | 717.0 |
| SR3 | -3405N | +3045E | 727.4 | NR6 | +1170N | -3500E | 751.0 |
| A2 | -3550N | +2650E | 727.0 | 03-1 | +1775N | -3770E | 719.4 |
| SR2 | -2725N | +2492E | 727.4 | NR7 | +1110N | -3834E | 751.0 |
| A1 | -3150N | +1990E | 720.0 | 03-6 | +2170N | -4765E | 727.3 |
| SR1 | -2167N | +1747E | 726.7 | NR8 | +1770N | -5550E | 733.5 |
| SH7 | -1075N | +1952E | 737.0 | NR9 | +1895N | -5870E | 732.0 |
| SH8 | -993N | +1967E | 735.5 | 04-3 | +1875N | -5935E | 727.3 |
| SH2 | -916N | +1865E | 737.6 | NR10 | +2315N | -6010E | 729.3 |
| SH3 | -860N | +1910E | 740.0 | 04-1 | +2280N | -6040E | 725.6 |
| SH4 | -806N | +1856E | 737.0 | NR11 | +1500N | -5735E | 729.3 |
| SH9 | -681N | +1960E | 732.1 | 04-4 | +1565N | -5800E | 721.6 |
| NH1 | -471N | +1853E | 736.4 | | | | |

## Table 3 - Summary of road sections

| No. | Section | Length (m) | Diff. in Elev. | | Grade (%) |
|---|---|---|---|---|---|
| | | | + | - | |
| 1 | NH1-NR1 | 1 140 | 1.8 | - | 0.16 |
| 2 | NR1-NR2 | 220 | - | 1.3 | 0.59 |
| 3 | NR2-NR3 | 960 | - | 16.3 | 1.70 |
| 4 | NR3-NR4 | 1 545 | 15.7 | - | 1.02 |
| 5 | NR4-NR5 | 1 225 | - | 15.5 | 1.27 |
| 6 | NR5-NR6 | 790 | 1.0 | - | 0.13 |
| 7 | NR6-NR7 | 340 | 0.0 | - | 0.00 |
| 8 | NR7-NR8 | 2 055 | 17.5 | - | 0.85 |
| 9 | NR8-NR9 | 345 | 1.5 | - | 0.43 |
| 10 | NR9-NR10 | 480 | 2.7 | - | 0.56 |
| 11 | NR9-NR11 | 510 | 2.7 | - | 0.53 |
| 12 | NR5-03-4 | 1 070 | 20.5 | - | 1.92 |
| 13 | NR6-03-1 | 670 | 33.6 | - | 5.01 |
| 14 | NR7-03-6 | 1 430 | 23.7 | - | 1.66 |
| 15 | NR10-04-1 | 55 | 3.7 | - | 6.72 |
| 16 | NR9-04-3 | 80 | 4.7 | - | 5.88 |
| 17 | NR11-04-4 | 55 | 7.7 | - | 14.00 |
| 18 | NR2-ST2 | 210 | - | 0.0 | 0.05 |
| 19 | NR1-ST1 | 130 | - | 12.8 | 9.85 |
| 20 | SH7-SR1 | 1 320 | 11.2 | - | 0.85 |
| 21 | SR1-SR2 | 950 | - | 0.7 | 0.07 |
| 22 | SR2-SR3 | 900 | 0.0 | - | 0.00 |
| 23 | SR3-SR4 | 435 | - | 0.3 | 0.07 |
| 24 | SR4-SR5 | 655 | - | 1.2 | 0.18 |
| 25 | SR5-SR6 | 580 | 0.9 | - | 0.16 |
| 26 | SR6-SR9 | 305 | - | 12.0 | 0.40 |
| 27 | SR9-SR7 | 520 | 3.0 | - | 0.58 |
| 28 | SR7-SR8 | 210 | - | 1.5 | 0.71 |
| 29 | SR8-SR10 | 1 520 | - | 6.5 | 0.43 |
| 30 | SR10-SR11 | 950 | - | 0.2 | 0.02 |
| 31 | SR11-KH1 | 2 160 | - | 21.4 | 0.99 |
| 32 | KH1-KH2 | 280 | 2.6 | - | 0.93 |
| 33 | KH2-KH3 | 240 | 0.2 | - | 0.08 |
| 34 | KH3-KH1 | 320 | - | 2.8 | 0.88 |
| 35 | SR2-A1 | 650 | 7.4 | - | 1.14 |
| 36 | SR3-A2 | 430 | 0.4 | - | 0.09 |
| 37 | SR5-02-1 | 715 | 3.9 | - | 0.55 |
| 38 | SR6-02-3 | 580 | 3.0 | - | 0.52 |
| 39 | SR7-02-5 | 400 | 12.0 | - | 3.00 |
| 40 | NH1-NH5 | 125 | - | 3.6 | 2.88 |
| 41 | NH5-NH6 | 135 | 3.3 | - | 2.44 |
| 42 | NH5-NH10 | 305 | 8.0 | - | 2.62 |
| 43 | NH10-NH6 | 380 | - | 4.7 | 1.24 |
| 44 | NH6-NH1 | 160 | 0.3 | - | 0.19 |
| 45 | NH1-SH4 | 350 | - | 0.6 | 0.17 |
| 46 | SH4-SH2 | 100 | - | 0.6 | 0.60 |
| 47 | SH2-SH3 | 80 | 2.4 | - | 3.00 |
| 48 | SH3-SH9 | 185 | 7.9 | - | 4.27 |
| 49 | SH3-SH4 | 115 | 3.0 | - | 2.61 |
| 50 | SH9-NH10 | 600 | 0.1 | - | 0.02 |
| 51 | SH2-SH7 | 180 | - | 0.3 | 0.17 |
| 52 | SH7-SH8 | 80 | 2.4 | - | 3.00 |
| 53 | SH8-SH9 | 300 | 3.4 | - | 1.13 |
| 54 | NH10-AL1 | 160 | 1.9 | - | 1.19 |
| 55 | AL1-AL2 | 150 | 0.1 | - | 0.07 |
| 56 | AL2-AL3 | 80 | 0.0 | - | 0.00 |
| 57 | SL3-AL1 | 75 | - | 0.1 | 0.13 |

## Table 4 - Euclid R85 (77T) travel times

| Truck #/ Section | 1267 | | 1268 | | 1269 | | 1270 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | E | F | E | F | E | F | E | F | E | F |
| SR2-SR1 | 72.39 | 72.64 | 68.64 | 66.82 | 70.11 | 67.28 | 72.37 | 70.40 | 70.33 | 68.64 |
| SR1-SH7 | 65.37 | 65.11 | 63.35 | 66.76 | 73.23 | 70.00 | 52.00 | 64.21 | 65.93 | |
| NH6-NH1 | - | 22.29 | - | 17.03 | - | 24.58 | - | 25.65 | - | 21.88 |
| NH1-SH4 | - | 30.86 | - | 33.12 | - | 40.78 | - | 46.94 | - | 36.87 |
| SH4-SH2 | - | 15.16 | - | 16.89 | - | 18.50 | - | 19.25 | - | 16.87 |
| SH9-NH10 | 37.68 | - | 32.31 | - | 37.58 | - | 37.00 | - | 35.88 | - |
| NH10-NH6 | - | 20.18 | - | 17.97 | - | 23.33 | - | 26.41 | - | 21.38 |
| SH7-SH8 | 30.35 | - | 31.94 | -35.14 | - | 29.67 | 32.15 | - | | |
| SH8-SH9 | 16.06 | - | 17.82 | - | 24.29 | - | 18.00 | - | 19.06 | - |
| SH7-SH2 | - | 41.27 | - | 36.41 | - | 44.15 | - | 38.30 | - | 40.14 |
| NH1-SH7 | - | 57.43 | - | 61.45 | - | 58.67 | | | | |

## Table 5 - Euclid R85 (91T) travel times

| Truck #/ Section | 1271 | | 1272 | | 1330 | | 1329 | | 1331 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E | F | E | F | E | F | E | F | E | F | E | F |
| KH1-KH2 | - | - | - | 48.71 | - | - | - | - | - | - | - | 48.71 |
| KH2-KH2 | - | - | 21.35 | - | - | - | - | - | - | - | 21.35 | - |
| KH2-KH3 | - | - | 29.00 | - | - | - | - | - | - | - | 29.00 | - |
| KH3-KH1 | - | - | 132.47 | - | - | - | - | - | - | - | 132.47 | - |
| KH1-SR11 | 151.25 | 221.50 | - | - | 140.00 | 225.50 | 143.00 | 209.00 | 152.00 | 211.00 | 146.70 | 217.50 |
| SR11-SR10 | 66.0 | 85.75 | - | - | 60.40 | 69.75 | 56.67 | 71.00 | 58.50 | 82.50 | 60.63 | 78.14 |
| SR10-SR8 | 105.25 | 130.00 | 114.24 | 130.64 | 109.60 | 116.25 | 105.67 | 126.50 | 109.50 | 131.75 | 111.09 | 128.58 |
| SR8-SR7 | 91.43 | 11.5 | 9.80 | 11.25 | 8.00 | 10.00 | 9.00 | 8.50 | 9.00 | 21.00 | 9.13 | 13.00 |
| SR7-SR9 | 36.57 | 55.63 | 37.00 | 54.5 | 33.50 | 44.50 | 34.33 | 47.00 | 34.57 | 49.00 | 35.30 | 52.53 |
| SR9-SR6 | 46.00 | 86.71 | - | - | 32.50 | 63.00 | 39.44 | 82.50 | 47.43 | 84.30 | 42.96 | 82.57 |
| SH6-SR5 | 44.00 | 50.00 | 36.00 | 45.50 | 39.50 | - | 51.00 | 66.60 | 40.75 | 45.00 | 44.80 | 56.90 |
| SR5-SR4 | 40.50 | 49.00 | 39.00 | 44.50 | 47.00 | - | 33.17 | 34.60 | 41.00 | 48.00 | 38.29 | 40.80 |
| SR4-SR3 | - | - | - | - | - | - | 88.0 | 93.0 | - | - | 88.00 | 93.00 |
| SR3-SR2 | - | - | - | - | - | - | 72.00 | 70.00 | - | - | 72.00 | 70.00 |
| SR2-SR1 | - | 66.00 | - | - | - | - | 49.00 | 76.78 | - | 66.00 | 49.00 | 74.82 |
| SR1-SH7 | - | - | 65.67 | 98.67 | - | - | 64.25 | 102.27 | - | 85.00 | 64.86 | 100.11 |
| NR9-NR8 | - | - | 82.64 | 128.36 | - | - | 69.57 | 115.17 | 72.73 | 168.47 | 75.97 | 143.29 |
| NR7-NR6 | - | - | 25.62 | 34.76 | - | - | 28.96 | 55.19 | 27.70 | 38.07 | 27.34 | 42.70 |
| NR6-NR5 | - | - | 63.50 | 190.30 | 61.29 | 174.50 | 55.79 | 72.40 | 101.00 | 23.40 | 60.22 | 123.72 |
| NR5-NR4 | - | - | 99.50 | 115.83 | 108.[illegible] | 113.29 | 97.62 | 112.44 | 102.00 | 90.00 | 103.43 | 112.66 |
| NR4-NR2 | - | - | 77.40 | 75.00 | - | - | 74.00 | - | 77.00 | 81.00 | 76.89 | 76.50 |
| NR2-NR1 | 90.5 | 96.87 | 90.75 | 91.13 | 16.33 | 91.43 | 119.52 | 90.36 | - | - | 126.45 | 91.66 |
| NR1-NH1 | - | - | 101.00 | 50.00 | - | - | 92.00 | 84.00 | 91.00 | 104.67 | 93.75 | 89.60 |
| NR1-ST1 | - | - | - | 22.33 | - | - | - | - | - | - | - | 22.33 |
| ST1-ST1 | - | - | 93.33 | - | - | - | - | - | - | - | 93.33 | - |
| ST1-ST2 | - | - | 15.33 | - | - | - | - | - | - | - | 15.33 | - |
| ST2-NR2 | - | - | 29.00 | - | - | - | - | - | - | - | 29.00 | - |
| NH1-NH5 | - | 33.86 | - | 64.57 | - | 52.43 | - | 58.83 | - | 33.00 | - | 54.19 |
| NH5-NH6 | 20.71 | - | 19.25 | - | 25.02 | - | 14.48 | - | 18.00 | - | 19.58 | - |
| NH5-NH6 | 31.29 | - | 29.64 | - | 50.2 | - | 29.62 | - | 30.00 | - | 36.68 | - |
| NH6-NH1 | 16.86 | - | 20.75 | - | 16.68 | - | 15.96 | - | 27.50 | - | 17.34 | - |
| NH1-SH4 | - | - | 30.25 | 47.40 | 46.32 | - | 35.00 | 44.53 | - | - | 31.20 | - |
| SH4-SH2 | - | - | - | 40.00 | - | - | 22.75 | - | - | 19.00 | 46.10 | 29.50 |
| SH2-SH3 | - | - | - | 40.12 | - | 30.70 | - | 40.53 | - | 33.00 | - | 36.55 |
| SH3-SH4 | - | - | - | - | - | - | 49.00 | - | - | - | 49.00 | - |
| SH3-SH9 | - | - | 23.06 | - | 21.16 | - | 17.80 | - | 38.00 | - | 21.14 | - |
| SH9-NH1 | - | - | 30.71 | - | 26.00 | - | 37.15 | - | - | - | 27.80 | - |
| SH9-NH5 | - | - | - | 35.6 | - | - | - | 41.0 | - | - | - | 36.50 |
| NH10-NH6 | - | - | 40.00 | - | - | - | 11.00 | - | 25.50 | - | | - |
| SH7-SH8 | - | - | - | - | - | - | - | 39.00 | - | - | - | 39.00 |
| SH8-SH3 | - | - | - | - | - | - | - | 42.40 | - | - | - | 42.40 |
| SH7-SH2 | - | - | - | - | - | - | 35.75 | - | - | - | 35.75 | - |

Table 6 - Cat 772 (91T) travel times

| Truck #/ Section | 7836 | | 7815 | | Total | |
|---|---|---|---|---|---|---|
| | E | F | E | F | E | F |
| KH1-KH2 | - | - | - | 63.59 | - | 63.59 |
| KH2-KH2 | - | - | 23.00 | - | 34.00 | - |
| KH2-KH3 | - | - | 35.14 | - | 35.14 | - |
| KH3-KH1 | - | - | 35.55 | - | 35.55 | - |
| KH1-SR11 | - | - | 117.10 | 184.10 | 117.10 | 184.10 |
| SR11-SR10 | - | - | 54.20 | 86.89 | 54.20 | 86.89 |
| SR10-SR8 | - | - | 110.00 | 176.96 | 110.00 | 176.96 |
| SR8-SR7 | - | - | 10.00 | 14.29 | 10.00 | 14.29 |
| SR7-SR9 | - | - | 40.40 | 54.50 | 40.40 | 54.50 |
| SR9-SR6 | - | - | 33.00 | - | 33.00 | - |
| SR6-SR5 | - | - | 51.00 | 82.00 | 51.00 | 82.00 |
| SR5-SR4 | - | 60.00 | 32.00 | 44.00 | 32.00 | 48.33 |
| SR4-SR3 | - | 49.00 | 115.0 | 104.00 | 115.0 | 104.00 |
| SH3-SH2 | 63.00 | 90.50 | - | - | 63.00 | 90.50 |
| SH2-SH1 | 50.82 | 82.18 | 54.58 | 87.00 | 52.38 | 84.36 |
| SH1-Sh7 | - | 170.00 | 58.57 | 134.62 | 58.87 | 138.56 |
| NH6-NH5 | - | 101.00 | - | - | - | 101.00 |
| NH5-NH4 | 103.25 | 154.29 | - | 103.25 | 154.29 | |
| NH4-NH3 | 81.38 | 184.23 | 81.38 | 184.23 | | |
| NH3-NH2 | - | - | 57.00 | - | 57.00 | - |
| NH5-NH5 | 18.61 | - | 45.85 | - | 26.24 | - |
| NH5-NH6 | 26.69 | - | 33.50 | - | 28.05 | - |
| NH6-NH1 | 14.44 | - | 19.00 | - | 15.53 | - |
| NH1-SH4 | - | - | 31.40 | - | 31.40 | - |
| NH1-SH2 | - | 60.23 | - | - | - | 60.23 |
| SH4-SH2 | - | - | - | 31.0 | - | 31.00 |
| SH2-SH3 | - | 74.15 | - | 43.00 | - | 71.93 |
| SH3-SH3 | 26.74 | - | 25.00 | - | 26.57 | - |
| SH3-SH4 | 27.50 | - | - | - | 27.50 | - |
| SH3-SH9 | 41.92 | - | 62.00 | - | 43.47 | - |
| SH9-NH1 | 31.50 | - | - | - | 31.50 | - |
| SH9-NH5 | - | 38.43 | - | 57.83 | - | 47.38 |
| NH10-NH6 | - | - | 11.00 | - | 11.00 | - |
| SH7-SH8 | - | 14.43 | - | 49.00 | - | 18.75 |
| SH8-SH3 | - | 39.86 | - | 36.00 | - | 39.38 |
| SH4-SH7 | 38.38 | - | - | - | - | - |

Tables 5-8 summarize the travel times for full and empty trucks at the different sections of the mine. It is apparent from the tables that some trucks are permanently allocated to one pit only, and some are on various assignments at different pits. For example, Kress trucks Nos. 8363 and 8312 run only between the Sundance hopper and Pit 03, Terex truck 8031 and Cat 7836 were assigned to the Keephills dump and so on. These assignments are left to the discretion of the mine operator and are essentially random selections. Apparently, it is coincidental that during our study (at various times of the year) these trucks were allocated, to the same location. However, it was found to be not intentional.

Tables, 9 and 10 summarize the average travel times for each group of trucks between the pits and dumps. Table 9 is a summary of the loaded trucks and Table 10 that of the empty trucks.

The fastest, fully loaded trucks travelling between various pits and dumps are the Kress trucks. The slowest, fully loaded trucks, are the Cat trucks in the section from Pit 02S and Pit 03 to Sundance dump, the Euclid trucks between Pit 02S and the Keephills dump, and the Terex truck between Pit 04 and the Sundance dump. It is apparent, that Cat trucks are generally slower when moving uphill as is the case on road from Pit 02S to the Sundance dump.

Table 7 - Terex 34-11C (136T) travel times

| Truck #/ Section | 8031 | | 8032 | | 8029 | | 8030 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | E | F | E | F | E | F | E | F | E | F |
| KH1-KH2 | - | - | - | 39.12 | - | 50.70 | - | 38.00 | 1 - 00 | 44.21 |
| KH2-KH2 | - | - | 27.28 | - | 23.16 | - | 16.00 | - | 25.08 | - |
| KH2-KH3 | - | - | 27.53 | - | 30.14 | - | 29.00 | - | 28.73 | - |
| KH3-KH1 | - | - | 32.00 | - | 54.37 | - | 24.00 | - | 41.64 | - |
| KH1-SR11 | - | - | 132.86 | 184.57 | 124.40 | 173.40 | 122.00 | 181.50 | 128.29 | 180.14 |
| SR11-SR10 | - | - | 63.00 | 125.07 | 53.00 | 82.90 | 60.50 | 73.50 | 59.20 | 105.63 |
| SR10-SR8 | 164.00 | 140.00 | 98.53 | 136.23 | 99.40 | 152.31 | 82.00 | 111.50 | 99.46 | 142.54 |
| SR8-SR7 | 6.00 | 12.00 | 11.62 | 14.17 | 12.37 | 12.61 | - | - | 11.65 | 13.31 |
| SR7-SR9 | 49.00 | 41.00 | 36.30 | 55.78 | 32.20 | 112.50 | 33.79 | - | 35.10 | 83.40 |
| SR9-SR6 | 32.33 | 33.17 | 34.75 | - | 36.50 | - | 31.13 | - | 33.32 | 33.17 |
| SR6-SR5 | 38.89 | 57.75 | 49.71 | 60.57 | 47.40 | 70.33 | 43.20 | 55.86 | 44.91 | 59.97 |
| SR5-SR4 | 35.86 | 42.36 | 30.17 | 44.47 | 32.67 | 38.12 | 35.95 | 37.17 | 33.54 | 40.59 |
| SR4-SR2 | 78.29 | 89.43 | 85.27 | 94.53 | - | - | 77.22 | 82.61 | 80.48 | 90.41 |
| SR2-SR1 | 47.84 | 59.20 | 54.14 | 69.69 | 47.30 | 100.30 | 40.87 | 66.00 | 47.97 | 70.06 |
| SR1-SH7 | 57.29 | 91.43 | 62.14 | 104.93 | 67.20 | 125.70 | 58.04 | 86.67 | 60.67 | 99.34 |
| NR9-NR8 | 65.45 | 128.75 | - | - | 67.50 | 174.82 | - | - | 66.43 | 150.78 |
| NR8-NR7 | 72.91 | 127.17 | - | - | 75.20 | 194.36 | - | - | 74.00 | 159.30 |
| NR7-NR6 | 18.18 | 34.82 | - | - | 33.08 | 78.53 | 43.50 | 115.00 | 30.30 | 56.55 |
| NR6-NR5 | 64.00 | - | - | - | 58.89 | 94.70 | 55.40 | 86.37 | 59.29 | 91.00 |
| NR5-NR4 | 89.00 | 72.00 | 81.00 | 85.67 | - | 45.40 | 89.40 | 75.80 | 78.62 | 75.39 |
| NR4-NR3 | 188.50 | 176.00 | 107.50 | 162.30 | 98.00 | 146.50 | - | - | 138.00 | 159.32 |
| NR3-NR2 | 84.00 | 61.00 | 71.75 | 78.29 | - | 51.00 | 86.00 | 88.00 | 77.57 | 76.77 |
| NR2-NH1 | 81.33 | 71.60 | - | 87.00 | - | - | - | - | 81.33 | 71.60 |
| NH1-NH5 | - | 42.82 | - | 29.00 | - | 31.00 | - | - | - | 41.47 |
| NH5-NH5 | 208.25 | - | 18.50 | - | 29.46 | - | 43.75 | - | 24.59 | - |
| NH5-NH6 | 26.39 | - | 30.50 | - | 27.34 | - | 36.00 | - | 27.40 | - |
| NH6-NH1 | 16.59 | - | 15.67 | - | 16.25 | - | 28.67 | - | 17.16 | - |
| NH1-SH4 | 29.68 | - | - | - | 31.50 | - | 33.67 | - | 30.67 | - |
| SH4-SH2 | 23.91 | - | 25.60 | - | 24.13 | - | 20.82 | - | 23.61 | - |
| SH2-SH3 | - | 28.50 | - | 28.67 | - | 38.00 | - | - | - | 30.17 |
| SH3-SH3 | 20.21 | - | 25.58 | - | 25.18 | - | 31.75 | - | 26.20 | - |
| SH3-SH4 | 25.92 | - | 25.23 | - | 26.80 | - | 24.37 | - | 25.36 | - |
| SH3-SH9 | 24.50 | - | 30.67 | - | 25.00 | - | - | - | 27.67 | - |
| SH9-NH1 | 26.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26.00 | - |
| SH9-NH5 | - | 43.82 | - | - | - | 44.67 | - | 70.75 | - | 47.39 |
| NH10-NH6 | 12.50 | - | - | - | - | - | - | - | 12.50 | - |
| SH7-SH8 | - | 40.00 | - | 38.50 | - | 41.67 | - | 25.85 | - | 38.42 |
| SH8-SH3 | - | 32.92 | - | 27.59 | - | 31.00 | - | 26.45 | - | 28.80 |
| SH7-SH2 | 32.44 | - | 34.19 | - | 30.50 | - | 34.13 | - | 36.56 | - |
| SH4-SH7 | 31.00 | - | 33.50 | - | 35.50 | - | - | - | - | - |
| NH5-NH10 | 40.00 | - | 39.00 | - | 41.00 | - | 50.00 | - | - | - |
| NH10-NH1 | - | - | - | - | 18.00 | - | - | - | - | - |

Table 8 - Kress CH-160 (145T) travel times

| Truck #/ Section | 8303 | | 8304 | | 8312 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | E | F | E | F | E | F | E | F |
| KH1-SR11 | 147.50 | 204.00 | - | - | 135.30 | 197.30 | 140.18 | 199.98 |
| SH8-SR7 | - | - | - | - | 6.50 | 8.00 | 6.50 | 8.00 |
| SR7-SH9 | - | - | 37.00 | 44.00 | 22.50 | 40.00 | 27.33 | 41.33 |
| SR7-SR6 | - | - | 32.00 | 29.00 | 33.55 | 73.55 | 33.00 | 58.67 |
| SR3-SR2 | - | - | 70.40 | 68.33 | - | - | 70.40 | 68.33 |
| SR2-SR1 | - | - | 47.53 | 61.31 | - | - | 47.53 | 61.31 |
| SR1-SH7 | 59.00 | - | 54.00 | 71.00 | - | - | 56.50 | 71.00 |
| NR9-NR8 | 105.00 | 133.17 | - | - | 90.00 | 96.00 | 103.31 | 130.31 |
| NR9-NR7 | 71.55 | 150.92 | - | - | 69.50 | 115.00 | 71.23 | 148.16 |
| NR7-NR6 | 15.09 | 31.23 | - | - | 27.14 | 35.09 | 23.12 | 33.73 |
| NR6-NR5 | - | - | 45.50 | 153.00 | 45.50 | 153.00 | | |
| NR5-NR4 | 64.80 | 71.67 | 82.75 | 104.75 | 70.60 | 69.60 | 72.00 | 88.48 |
| NR4-NR3 | - | - | 78.20 | 97.42 | - | - | 78.20 | 97.42 |
| NR3-NR2 | 72.00 | 71.50 | - | 37.00 | - | 63.00 | 72.00 | 60.75 |
| NR1-ST1 | - | - | - | 31.50 | - | - | - | 31.50 |
| ST1-ST2 | - | - | 25.00 | - | - | - | 25.00 | - |
| ST2-NR2 | - | - | 67.00 | - | - | - | 67.00 | - |
| NH5-NH5 | - | - | 41.00 | - | - | - | 41.00 | - |
| NH5-NH6 | - | - | 24.00 | - | - | - | 24.00 | - |
| NH6-NH1 | - | - | 16.00 | - | - | - | 16.00 | - |
| NH1-SH4 | - | - | - | 45.43 | - | - | - | 45.43 |
| SH4-SH2 | - | - | - | 18.00 | - | - | - | 180.00 |
| SH2-SH3 | - | - | - | 42.44 | - | - | - | 42.44 |
| SH3-SH3 | - | - | 23.19 | - | - | - | 23.19 | - |
| SH3-SH4 | - | - | 24.50 | - | - | - | 24.50 | - |
| SH3-SH9 | - | - | 34.20 | - | - | - | 34.20 | - |
| SH9-NH1 | - | - | 29.71 | - | - | - | 29.71 | - |
| SH9-NH5 | - | - | - | 41.00 | - | - | - | 41.00 |
| SH7-SH8 | - | - | - | 13.17 | - | - | - | 13.17 |
| SH8-SH3 | - | - | - | 22.50 | - | - | - | 22.50 |
| SH4-SH7 | - | - | 32.40 | - | - | - | - | - |

The Cat trucks are however quite acceptable on the long level runs, such as between Pit 02S and the Keephills dump. The Terex trucks were acceptable on the long downhill runs from Pit 03 to the Sundance dump, but totally unacceptable on the long runs with a slight uphill section, such as between Pit 04 and the Sundance dump.

The fastest empty trucks were again Kress trucks. The Cat trucks were the slowest driving uphill and on the long runs to Pits 03 and 04 from the Sundance dump, but quite acceptable to drive downhills on long run from the Keephills dump to Pit 02S.

Table 11 summarizes the average dumping times at the Sundance and Keephills dumps. At the Sundance dump, the average time was calculated separately for the north hopper (NH5) and for the south hopper (SH3). The dumping times were expected to be shorter for the smaller trucks than for the larger trucks. However, this was not proven to be the case during the study. For example the Euclid and Kress trucks had shorter dumping times than the Cat and Terex trucks at both dumps.

Table 9 - Average travel times(sec) - loaded trucks

| Section | Euclid 77T | Euclid 91T | Cat 91T | Terex 136T | Kress 145T |
|---|---|---|---|---|---|
| Pit 2S - Sundance (SR6-SH7 | - | 365.63 | 476.00 | 380.66 | 351.45 |
| Pit 2S - Keephills (SR6-KH1) | - | 572.32 | 496.32 | 558.19 | 479.21 |
| Pit 3 - Sundance (NR5-NH1) | - | 406.65 | 474 81 | 393.78 | 362.48 |
| Pit 4 - Sundance (NR9-NH1) | - | 843.85 | 954.41 | 1063.17 | 808.93 |
| Ash load - Ash dump (NH10-SR2) | 271.71 | - | - | - | - |

Table 10 - Average travel times - empty trucks

| Section | Euclid 77T | Euclid 91T | Cat 91T | Terex 136T | Kress 145T |
|---|---|---|---|---|---|
| Pit 02S - Sundance (SH7-SR6) | - | 284.95 | 308.95 | 277.33 | 260.12 |
| Pit 02S - Keephills (KH1-SR6) | - | 405.81 | 364.71 | 398.73 | 344.35 |
| Pit 03 - Sundance (NH1-NR9) | - | 396.82 | 408.16 | 375.52 | 312.18 |
| Pit 04 - Sundance (NH1-NR9) | - | 652.32 | 684.20 | 605.54 | 574.21 |
| Ash dump - ash load (SR2-NH10) | 221.63 | - | - | - | - |

Table 11 - Average dumping times (sec).

| Truck | Sundance | | Keephills |
|---|---|---|---|
| | NH5 | SH3 | KH2 |
| Euclid 77T | - | - | - |
| Euclid 91T | 19.58 | 17.32 | 21.35 |
| Cat 91T | 26.24 | 26.57 | 23.00 |
| Terex 136T | 24.59 | 26.20 | 25.08 |
| Kress 145T | 21.00 | 23.19 | 22.18 |

Table 12 summarizes the average stay at the tipple area. The time spent at the Sundance tipple was established as the time when afully loaded truck passes point NH1, dump at north or south hopper and returns to point NH1 empty. The time needed for maneuvering to the south dump from Pits 03 and 04, or to the north dump from Pit 02S is longer than to the north dump from Pits 03 and 04 or to the south dump from Pit 02S respectively, because of the difference in travelled distance (see Fig. 1). The shortest dumping times are achieved by the Kress trucks, whereas the Euclid trucks have the longest dumping times.

Table 12 - Average stay at Tipple Area (sec.)

| Truck | Euclid 77T | Euclid 91T | Cat 91T | Terex 136T | Kress 145T |
|---|---|---|---|---|---|
| Sundance | | | | | |
| NH1-NH1: | | | | | |
| NH5 dump | N/A | 127.99 | 130.67 | 110.62 | 105.12 |
| SH3 dump | N/A | 152.84 | 235.87 | 159.68 | 174.97 |
| SH7-SH7: | | | | | |
| SH3 dump | N/A | 206.22 | 150.58 | 166.84 | 115.76 |
| NH5 dump | N/A | 235.14 | 174.31 | 196.12 | 135.14 |
| Keephills: | | | | | |
| KH1-KH1 | | | | | |
| KH2 dump | | 231.53 | 157.28 | 139.66 | 128.35 |

This average stay at tiple include dumping times, listed in Table 13. The average stay in the pit is shown in Table 13.

Table 13 - Average stay in pit (sec.)

| Pit no. | Euclid 91T | Cat 91T | Terex 136T | Kress 145T |
|---|---|---|---|---|
| 02S | 994.12 | 1 017.33 | 1 181.28 | 794.00 |
| 03 | 1 078.34 | 1 225.87 | 1 256.46 | 1 486.80 |
| 04 | 599.06 | - | 858.84 | 642.91 |

The "average stay in pit" includes time spent driving from the ramp entrance point to a loading shovel, queueing and loading and driving out of the pit by an exit ramp. As is apparent from Table 13, the shortest stay is in the Pit 04.

Tables 14 and 15 summarize the average travel speeds between pits and dumps.

Table 14 - Average travel speed (km/h) - loaded trucks

| Section | Euclid 77T | Euclid 91T | Cat 91T | Terex 136T | Kress 145T |
|---|---|---|---|---|---|
| Pit 02-Sundance (SR6-SH7) | - | 47.65 | 36.60 | 45.77 | 49.57 |
| Pit 02-Keephills (SR6-KH1) | - | 39.28 | 45.30 | 40.28 | 46.91 |
| Pit 03-Sundane (NR5-NH1) | - | 45.06 | 38.59 | 46.53 | 50.55 |
| Pit 04-Sundance (NR9-NH1) | - | 36.77 | 32.51 | 29.19 | 38.36 |
| Ash load-ash dump (NH10-SR2) | 44.58 | - | - | - | - |

Table 15 - Average travel speed (km/h) - empty trucks

| Section | Euclid 77T | Euclid 91T | Cat 91T | Terex 136T | Kress 145T |
|---|---|---|---|---|---|
| Pit 02S-Sundance (SH7-SR6) | - | 61.15 | 56.40 | 62.83 | 66.98 |
| Pit 02S-Keephills (KH1-SR6) | - | 55.40 | 61.64 | 56.38 | 65.29 |
| Pit 03-Sundance (NH1-NR5) | - | 46.18 | 44.89 | 48.80 | 58.70 |
| Pit 04-Sundance (NH1-NR9) | - | 47.57 | 45.36 | 51.25 | 54.04 |
| Ash dump-ash load (SR2-NH10) | 52.79 | - | - | - | - |

Again, Kress trucks proved to be the fastest trucks, transporting more coal in the shortest period of time.

In addition to the time study of trucks, historical data were reviewed (1) and the "TKPH" (ton-km-per hour) rating evaluated.

Assuming that Highvale Mine historical data for load factors apply here, the following tables summarize the values for the trucks travelling loaded from Pit 02S to the Sundanace dump (Table 16), from Pit 02S to the Keephills dump (Table 17), from Pit 03 to the Sundance dump (Table 18), from Pit 04 to the Sundance dump (Table 19), and from the ash load to the ash dump for the ash trucks (Table 20).

Table 16 - TKPH values (Pit 02S-Sundance)

| Truck | Empty truck (T) | Loaded truck (T) | Meantime load (T) | Ave. speed (KPH) | TKPH |
|---|---|---|---|---|---|
| Euclid 91T | 59.6 | 81.8 | 70.7 | 54.4 | 3 846 |
| Cat 91T | 33.3 | 81.8 | 57.8 | 46.5 | 2 688 |
| Terex 136T | 82.1 | 130.9 | 106.5 | 54.3 | 5 783 |
| Kress 145T | 63.5 | 138.3 | 100.9 | 58.3 | 5 882 |

Table 17 - TKPH values (Pit 02-Keephills)

| Truck | Empty truck (T) | Loaded truck (T) | Meantime load (T) | Ave. speed (T) | TKPH |
|---|---|---|---|---|---|
| Euclid 91T | 59.6 | 81.8 | 70.7 | 47.3 | 3 344 |
| Cat 91T | 33.3 | 81.8 | 57.8 | 53.5 | 3 092 |
| Terex 136T | 82.1 | 130.9 | 106.5 | 48.3 | 5 144 |
| Kress 145T | 63.5 | 138.3 | 100.9 | 56.1 | 5 660 |

Table 18 - TKPH values (Pit 03-Sundance)

| Truck | Empty truck (T) | Loaded truck (T) | Meantime load (T) | Ave. speed (T) | TKPH |
|---|---|---|---|---|---|
| Euclid 91T | 59.6 | 81.8 | 70.7 | 45.6 | 3 224 |
| Cat 91T | 33.3 | 81.8 | 57.8 | 41.7 | 2 410 |
| Terex 136T | 82.1 | 130.9 | 106.5 | 47.7 | 5 080 |
| Kress 145T | 63.1 | 138.3 | 100.9 | 54.9 | 5 509 |

Table 19 - TKPH values (Pit 04-Sundance)

| Truck | Empty truck (T) | Loaded truck (T) | Meantime load (T) | Ave. speed (T) | TKPH |
|---|---|---|---|---|---|
| Euclid 91T | 59.9 | 81.8 | 70.7 | 42.2 | 2 984 |
| Cat 91T | 33.3 | 81.8 | 57.8 | 38.9 | 2 248 |
| Terex 136T | 82.1 | 130.9 | 106.5 | 40.2 | 4 281 |
| Kress 145T | 63.5 | 138.3 | 100.9 | 46.2 | 4 662 |

Table 20 - TKPH values (Ash load-Ash dump)

| Truck | Empty truck (T) | Loaded truck (T) | Meantime load (T) | Ave. speed (T) | TKPH |
|---|---|---|---|---|---|
| Euclid 77T | 51.6 | 66.0 | 58.8 | 48.7 | 2 864 |

The "TKPH" values (Table 16-20) also indicate load distribution on all wheels of the truck. Each truck has its own load distribution characteristics on wheels (rate supplied by the manufacturer). In order to calculate the true load on each tire to assess the problem of overheating of the tires, the total load must be distributed to each axle and each tire. The load distribution on trucks used at Highvale Mine is shown on Table 21. The TKPH rating for each tire was calculated later and is summarized in Table 22 for Euclid 77T truck, in Table 23 for Cat 91T truck, in Table 24 for Terex 136T truck, and in Table 25 for Kress 145T rucks. The values in Tables 22 to 25 are for different section of High ale Mine, for the runs between various pits and dumps.

Table 21 - Truck load distribution

| Truck | No. of wheels | | | Distribution of weight (%) | | |
|---|---|---|---|---|---|---|
| | Front | Rear | Trailer | Front | Rear | Trailer |
| Euclid 77T | 2 | 4 | - | 32.79 | 67.21 | - |
| Euclid 91T | 2 | 4 | 4 | 12.90 | 43.88 | 43.22 |
| Cat 91T | 2 | 4 | 4 | 13.60 | 42.16 | 44.24 |
| Terex 136T | 2 | 4 | 4 | 14.11 | 41.87 | 44.02 |
| Kress 145T | 4 | 4 | - | 49.61 | 50.39 | - |

Table 22 - TKPH ratings per tire (Euclid 77T)

| Section | Total TKPH ratings | | | | TKPH ratings per tire | | |
|---|---|---|---|---|---|---|---|
| | TKPH | Front axle | Drive axle | Trailer | Front | Drive | Trailer |
| Sundance-pit 02S | 3 846 | 496 | 1 688 | 1 662 | 248 | 442 | 416 |
| Keephills-pit 02S | 3 344 | 431 | 1 467 | 1 446 | 216 | 367 | 362 |
| Sundance-pit 03 | 3 224 | 416 | 1 415 | 1 393 | 208 | 354 | 348 |
| Sundance-pit 04 | 2 984 | 385 | 1 309 | 1 290 | 192 | 327 | 322 |
| Average | 3 350 | 432 | 1 470 | 1 448 | 216 | 368 | 362 |

Table 23 - TKPH ratings per tire (Cat 91T)

| Section | Total TKPH ratings | | | | TKPH ratings per tire | | |
|---|---|---|---|---|---|---|---|
| | TKPH | Front axle | Drive axle | Trailer | Front | Drive | Trailer |
| Sundance-pit 02S | 2 688 | 366 | 1 133 | 1 189 | 183 | 283 | 297 |
| Keephills-pit 02S | 3 092 | 420 | 1 304 | 1 368 | 210 | 326 | 342 |
| Sundance-pit 03 | 2 410 | 328 | 1 016 | 1 063 | 164 | 254 | 266 |
| Sundance-pit 04 | 2 248 | 306 | 948 | 99490 | 153 | 237 | 248 |
| Average | 2 610 | 355 | 1 100 | 1 155 | 178 | 275 | 289 |

Table 24 - TKPH ratings per tire (Terex 136T)

| Section | Total TKPH ratings | | | | TKPH ratings per tire | | |
|---|---|---|---|---|---|---|---|
| | TKPH | Front axle | Drive axle | Trailer | Front | Drive | Trailer |
| Sundance-pit 02S | 5 783 | 816 | 2 421 | 2 546 | 408 | 605 | 636 |
| Keephills-pit 02S | 5 144 | 726 | 2 154 | 2 264 | 363 | 538 | 566 |
| Sundance-pit 03 | 5 080 | 717 | 2 127 | 2 236 | 358 | 532 | 559 |
| Sundance-pit 04 | 4 281 | 604 | 1 792 | 1 885 | 302 | 448 | 471 |
| Average | 5 072 | 716 | 2 124 | 2 232 | 358 | 531 | 558 |

Table 25 - TKPH ratings per tire (Kress 145T)

| Section | Total TKPH ratings | | | | TKPH ratings per tire | | |
|---|---|---|---|---|---|---|---|
| | TKPH | Front axle | Drive axle | Trailer | Front | Drive | Trailer |
| Sundance-pit 02S | 5 882 | 2 918 | 2 964 | - | 730 | 741 | - |
| Keephills-pit 02S | 5 660 | 2 808 | 2 852 | - | 702 | 713 | - |
| Sundance-pit 03 | 5 509 | 2 733 | 2 776 | - | 683 | 694 | - |
| Sundance-pit 04 | 4 662 | 2 313 | 2 349 | - | 578 | 587 | - |
| Average | 5 428 | 2 693 | 2 735 | - | 673 | 684 | - |

The summary of TKPH ratings averages per tire and for each type of truck used at any section of the Highvale Mine is in Table 26.

Table 26 - Average TKPH ratings

| Truck | TKPH ratings | | |
|---|---|---|---|
| | Front axle | Drive axle | Trailer |
| Euclid 77T | 470 | 481 | - |
| Euclid 91T | 216 | 368 | 362 |
| Cat 91T | 178 | 275 | 289 |
| Terex 136T | 358 | 531 | 558 |
| Kress 145T | 673 | 684 | - |

The averages of a TKPH ratings are compared in Table 26 with the recommended TKPH ratings supplied by manufacturers (6). The following is the most recent (June 1983) TKPH ratings as was made available by Goodyear and Bridgestone (7) for the following tire sizes (Table 27).

Table 27 - Tire sizes

| Truck | Front | Rear | Trailer |
|---|---|---|---|
| Euclid 77T | 24.00-49 | 24.00-49 | - |
| Euclid 91T | 24.00-49 | 24.00-49 | 24.00-49 |
| Cat 91T | 24.00-35 | 24.00-35 | 24.00-49 |
| Terex 136T | 27.00-49 | 27.00-49 | 27.00-49 |
| Kress 145T | 27.00-49 | 27.00-49 | - |

The tire sizes conform to E3 industry code, 3S custom code as per Goodyear and Bridgestone manufacture requirements. Using the information as in Table 27 and TKPH ratings at 38°C ambient temperature (6) for hauls of 30 km or less one way, the following values are recommended as TKPH ratings for Highvale Mine trucks (Table 28).

Table 28 - Recommended TKPH ratings

| Truck | Tires | | |
|---|---|---|---|
| | Front | Drive | Trailer |
| Euclid 77T | 234 | 321 | - |
| Euclid 91T | 321 | 321 | 321 |
| Cat 91T | 285 | 285 | 321 |
| Terex 136T | 321 | 321 | 321 |
| Kress 145T | 423 | 423 | - |

The values measured at the Highvale Mine exceed allowable limit for Euclid 77T ash trucks, Terex 136T and Kress 145T coal haulers. The Euclid 91T coal haulers and the Cat 91T coal haulers are within the prescribed limit.

The travel speed was also evaluated as a function of the time of the day (day shift only). It is concluded that by using data obtained during the year 1983, the following changes (in %) were measured (Table 29).

Table 29 - Average travel speed changes with time of the shift

| Time of shift/ change | Euclid 77T (%) | Euclid 91T (%) | Cat 91T (%) | Terex 136T (%) | Kress 145T (%) |
|---|---|---|---|---|---|
| 07:00-11:00 | 100* | 100* | 100* | 100* | 100* |
| 11:00-15:00 | -0.5 | -1.2 | ** | -1.7 | -0.8 |
| 15:00-19:00 | -0.2 | +2.3 | ** | +0.4 | +0.5 |

NOTE: *Time for 07:00 to 11:00 is 100%. Later changes are in % to first time section
**Not sufficient data

Only the Euclid 77T coal haulers have shown a significant variations in travel speed as a function of the time during the shift. However, this value has been determined to be so small (-1.2% and +2.3%) that at the present time and with the number of trucks used, there should not be any significant change to the daily production requirements.

## 2.2 TRUCK FUEL CONSUMPTION

Using historical data collected at Highvale Mine for the total number of operating hours and for the diesel fuel consumed, the following tables were developed to calculate the hourly fuel consumption rate. The summary of the operating hours and fuel consumption are for each group of trucks as follows: Table 30 is for Euclid 77T ash haulers, Table 31 for Euclid 91T, Table 32 for Cat 91T, Table 33 for Terex 136T and Table 34 for Kress 145T.

Table 30 - Fuel consumption: Euclid 77T

| Month | Operating hrs (hrs) | Fuel Consumption (ℓ) | Consumption (ℓ/hr) | Note |
|---|---|---|---|---|
| Apr/82 | 660 | 29 198 | 44 | |
| May/82 | 695 | 22 446 | 32 | Fuel tank capacity |
| Jun/82 | 669 | 24 852 | 37 | 1003 ℓ. |
| Jul/82 | 720 | 27 229 | 38 | |
| Aug/82 | 685 | 24 604 | 36 | Fueling every |
| Sep/82 | 675 | 23 474 | 35 | 23 hrs. 53 min |
| Oct/82 | 713 | 28 187 | 40 | or 0.335/8 hr shift |
| Nov/82 | 762 | 31 402 | 41 | |
| Dec/82 | 954 | 35 189 | 37 | |
| Jan/83 | 840 | 31 478 | 37 | |
| Feb/83 | 842 | 30 755 | 37 | |
| Mar/83 | 870 | 31 948 | 37 | |
| Apr/83 | 732 | 27 653 | 38 | |
| May/83 | 682 | 36 680 | 54 | |
| Jun/83 | 681 | 47 242 | 69 | |
| Jul/83 | 645 | 31 983 | 50 | |
| Aug/83 | 664 | 36 489 | 55 | |
| Sep/83 | 637 | 26 880 | 42 | |
| Oct/83 | 720 | 25 545 | 35 | |
| Nov/83 | 757 | 33 038 | 44 | |
| Dec/83 | 899 | 32 986 | 37 | |
| Jan/84 | 824 | 29 956 | 36 | |
| Feb/84 | 655 | 39 331 | 60 | |
| Average | 16 981 | 708 545 | 42 | |

## Table 31 - Fuel consumption: Euclid 91T

| Month | Operating hrs (hrs) | Fuel Consumption (ℓ) | Consumption (ℓ/hr) | Note |
|---|---|---|---|---|
| Apr/82 | 1 221 | 98 660 | 81 | |
| May/82 | 1 422 | 83 821 | 59 | Fuel tank capacity |
| Jun/82 | 1 591 | 107 862 | 68 | 776 ℓ |
| Jul/82 | 1 096 | 75 647 | 69 | |
| Aug/82 | 1 609 | 105 475 | 66 | Fueling every |
| Sep/82 | 1 770 | 112 231 | 63 | 10 hrs. 56 min |
| Oct/82 | 1 857 | 133 801 | 72 | or 1.098/12 hr shift |
| Nov/82 | 1 886 | 142 146 | 75 | |
| Dec/82 | 2 638 | 186 128 | 71 | |
| Jan/83 | 2 100 | 143 062 | 68 | |
| Feb/83 | 1 786 | 121 235 | 68 | |
| Mar/83 | 1 777 | 119 016 | 67 | |
| Apr/83 | 1 471 | 101 207 | 69 | |
| May/83 | 1 738 | 137 970 | 79 | |
| Jun/83 | 1 894 | 158 633 | 84 | |
| Jul/83 | 1 273 | 94 353 | 74 | |
| Aug/83 | 1 623 | 136 716 | 84 | |
| Sep/83 | 1 503 | 113 880 | 76 | |
| Oct/83 | 1 492 | 81 474 | 55 | |
| Nov/83 | 1 771 | 120 707 | 68 | |
| Dec/83 | 2 193 | 146 640 | 67 | |
| Jan/84 | 1 450 | 99 807 | 69 | |
| Feb/84 | 1 184 | 87 750 | 74 | |
| Average | 38 345 | 2 708 221 | 71 | |

## Table 32 - Fuel consumption: Cat 91T

| Month | Operating hrs (hrs) | Fuel Consumption (ℓ) | Consumption (ℓ/hr) | Note |
|---|---|---|---|---|
| Apr/82 | 512 | 35 109 | 69 | Starting Jan/84, |
| May/82 | 356 | 17 820 | 50 | trucks changed to |
| Jun/82 | 201 | 11 573 | 58 | water trucks |
| Jul/82 | 160 | 9 379 | 59 | |
| Aug/82 | 481 | 26 780 | 56 | Fuel tank capacity |
| Sep/82 | 251 | 13 509 | 54 | 680 ℓ |
| Oct/82 | 492 | 30 147 | 61 | |
| Nov/82 | 511 | 32 663 | 64 | Fueling every |
| Dec/82 | 818 | 52 532 | 64 | 11 hrs. 9 min |
| Jan/83 | 724 | 41 894 | 58 | or 1.076/12 hr shift |
| Feb/83 | 590 | 33 324 | 56 | |
| Mar/83 | 673 | 38 305 | 57 | |
| Apr/83 | 681 | 39 819 | 58 | |
| May/83 | 366 | 28 396 | 78 | |
| Jun/83 | 290 | 21 110 | 73 | |
| Jul/83 | 25 | 2 250 | 90 | |
| Aug/83 | 132 | 10 979 | 83 | |
| Sep/83 | 252 | 15 624 | 62 | |
| Oct/83 | 406 | 18 307 | 45 | |
| Nov/83 | 209 | 14 280 | 68 | |
| Dec/83 | 406 | 25 000 | 62 | |
| Jan/84 | - | - | - | |
| Feb/84 | - | - | - | |
| Average | 8 536 | 518 800 | 61 | |

## Table 33 - Fuel consumption: Terex 136T

| Month | Operating hrs (hrs) | Fuel Consumption (ℓ) | Consumption (ℓ/hr) | Note |
|---|---|---|---|---|
| Apr/82 | 971 | 115 984 | 119 | |
| May/82 | 1 202 | 104 823 | 87 | |
| Jun/82 | 1 440 | 249 254 | 173 | |
| Jul/82 | 1 370 | 139 897 | 102 | |
| Aug/82 | 1 607 | 155 853 | 97 | Fuel tank capacity |
| Sep/82 | 1 443 | 135 309 | 94 | 1230ℓ |
| Oct/82 | 1 354 | 144 412 | 107 | |
| Nov/82 | 1 872 | 208 848 | 112 | Fueling every |
| Dec/82 | 1 936 | 199 433 | 103 | 12 hrs. 18 min |
| Jan/83 | 1 865 | 188 247 | 101 | or 0.976/12 hr shift |
| Feb/83 | 1 429 | 141 088 | 99 | |
| Mar/83 | 1 557 | 154 367 | 99 | |
| Apr/83 | 1 501 | 152 897 | 102 | |
| May/83 | 1 639 | 172 260 | 105 | |
| Jun/83 | 1 216 | 109 260 | 90 | |
| Jul/83 | 1 290 | 112 332 | 87 | |
| Aug/83 | 1 264 | 110 740 | 88 | |
| Sep/83 | 1 739 | 187 056 | 108 | |
| Oct/83 | 1 769 | 149 430 | 84 | |
| Nov/83 | 1 771 | 175 917 | 99 | |
| Dec/83 | 1 927 | 166 577 | 86 | |
| Jan/84 | 1 675 | 146 799 | 88 | |
| Feb/84 | 1 092 | 82 782 | 76 | |
| Average | 34 929 | 3 503 565 | 100 | |

## Table 34 - Fuel consumption: Kress 145T

| Month | Operating hrs (hrs) | Fuel Consumption (ℓ) | Consumption (ℓ/hr) | Note |
|---|---|---|---|---|
| Apr/82 | - | - | - | |
| May/82 | - | - | - | |
| Jun/82 | - | - | - | |
| Jul/82 | - | | - | |
| Aug/82 | - | | - | Fuel tank capacity |
| Sep/82 | - | | - | 1135ℓ |
| Oct/82 | - | - | - | |
| Nov/82 | - | - | - | Fueling every |
| Dec/82 | - | - | - | 10 hrs. 8 min |
| Jan/83 | - | - | - | |
| Feb/83 | 398 | 41 687 | 105 | 2 units |
| Mar/83 | 839 | 88 573 | 106 | |
| Apr/83 | 899 | 152 897 | 170 | |
| May/83 | 894 | 123 625 | 138 | |
| Jun/83 | 878 | 88 439 | 101 | 3 units |
| Jul/83 | 1 027 | 85 159 | 83 | |
| Aug/83 | 984 | 85 204 | 87 | |
| Sep/83 | 1 175 | 156 975 | 134 | |
| Oct/83 | 976 | 228 571 | 234 | |
| Nov/83 | 1 265 | 132 604 | 105 | |
| Dec/83 | 1 310 | 109 184 | 83 | 4 units |
| Jan/84 | 1 922 | 165 366 | 86 | 5 units |
| Feb/84 | 1 776 | 141 668 | 80 | 6 units |
| Average | 14 343 | 1 599 952 | 112 | |

From the data in Tables 30 to 34, average fuel consumption was calculated for each type of trucks and read as follows:

Euclid 77T: 42 ℓ /hr.
Euclid 91T: 71 ℓ /hr.
Cat 91T: 61 ℓ /hr.
Terex 136T: 100 ℓ /hr.
Kress 145T: 112 ℓ /hr.

Using loading factor described in (1). the following fuel consumption for all trucks in litres per hour and ton were calculated (Table 35).

Table 35 - Fuel consumption (ℓ/hr/T)

| Truck | Load factor (T) | Fuel consumption | |
|---|---|---|---|
| | | (ℓ/hr) | (ℓ/hr/T) |
| Euclid 77T | 66.0* | 42 | 0.64 |
| Euclid 91T | 81.8 | 71 | 0.87 |
| Cat 91T | 81.8 | 63 | 0.77 |
| Terex 136T | 130.9 | 100 | 0.76 |
| Kress 145T | 138.3 | 116 | 0.84 |
| NOTE: *Average weight of wet fly and bottom ash used | | | |

The data in Table 35 indicate that Euclid 77T, Cat 91T and Terex 136T appear to be the best trucks in the fuel consumption. However, Kress 145T trucks are new at the mine and the data available for evaluation were quite limited.

These values from Tables 30 to 34 were also plotted on the graphs (Fig. 2-7). The graphs for different types of trucks can be identified as follows:

Fig. 2: Fuel consumption graph: Euclid 77T
Fig. 3: Fuel consumption graph: Euclid 91T
Fig. 4: Fuel consumption graph: Cat 91T
Fig. 5: Fuel consumption graph: Terex 136T
Fig. 6: Fuel consumption graph: Kress 145T

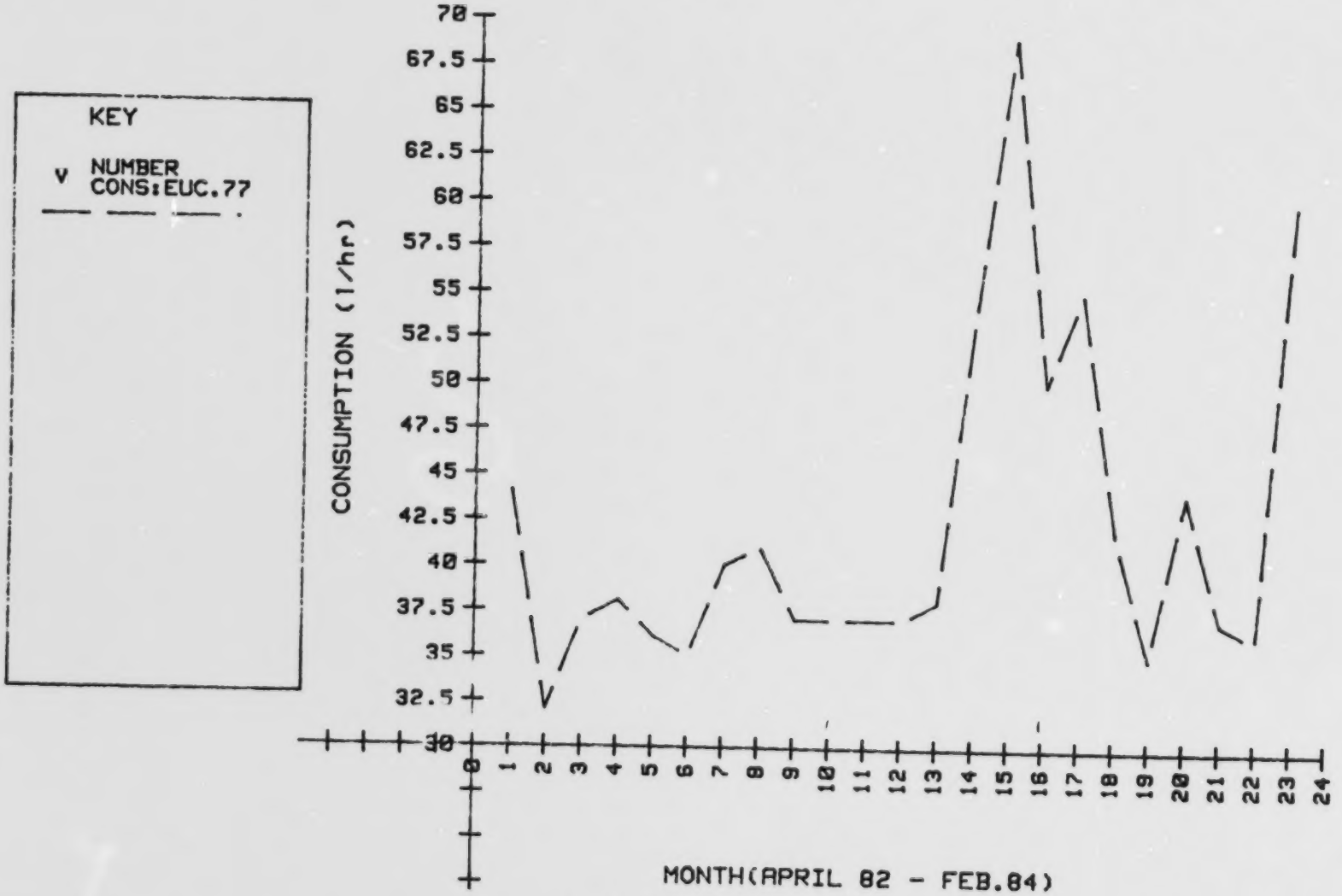



Fig. 2 - FUEL CONSUMPTION GRAPH
HIGHVALE MINE

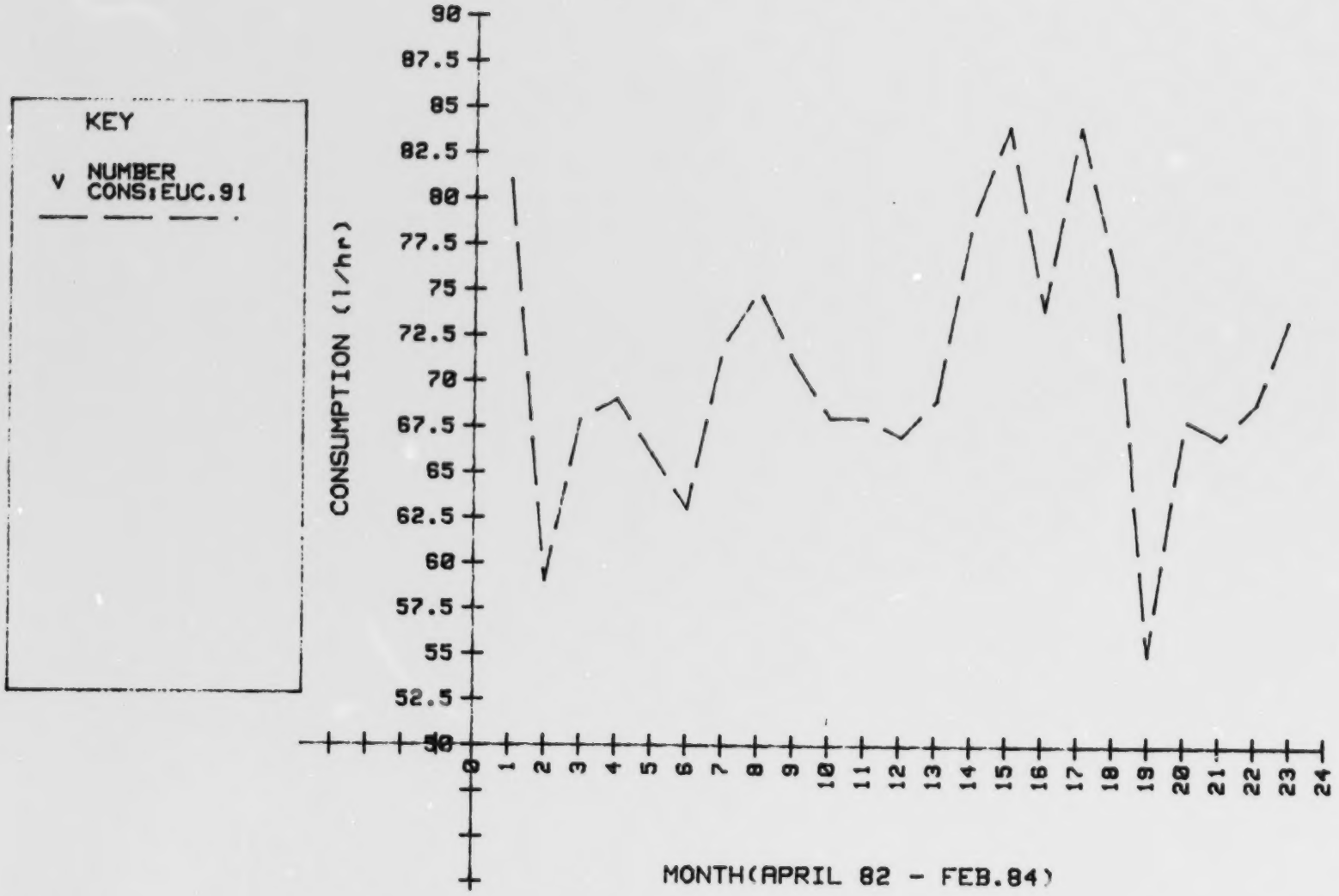



Fig. 3 - FUEL CONSUMPTION GRAPH
HIGHVALE MINE

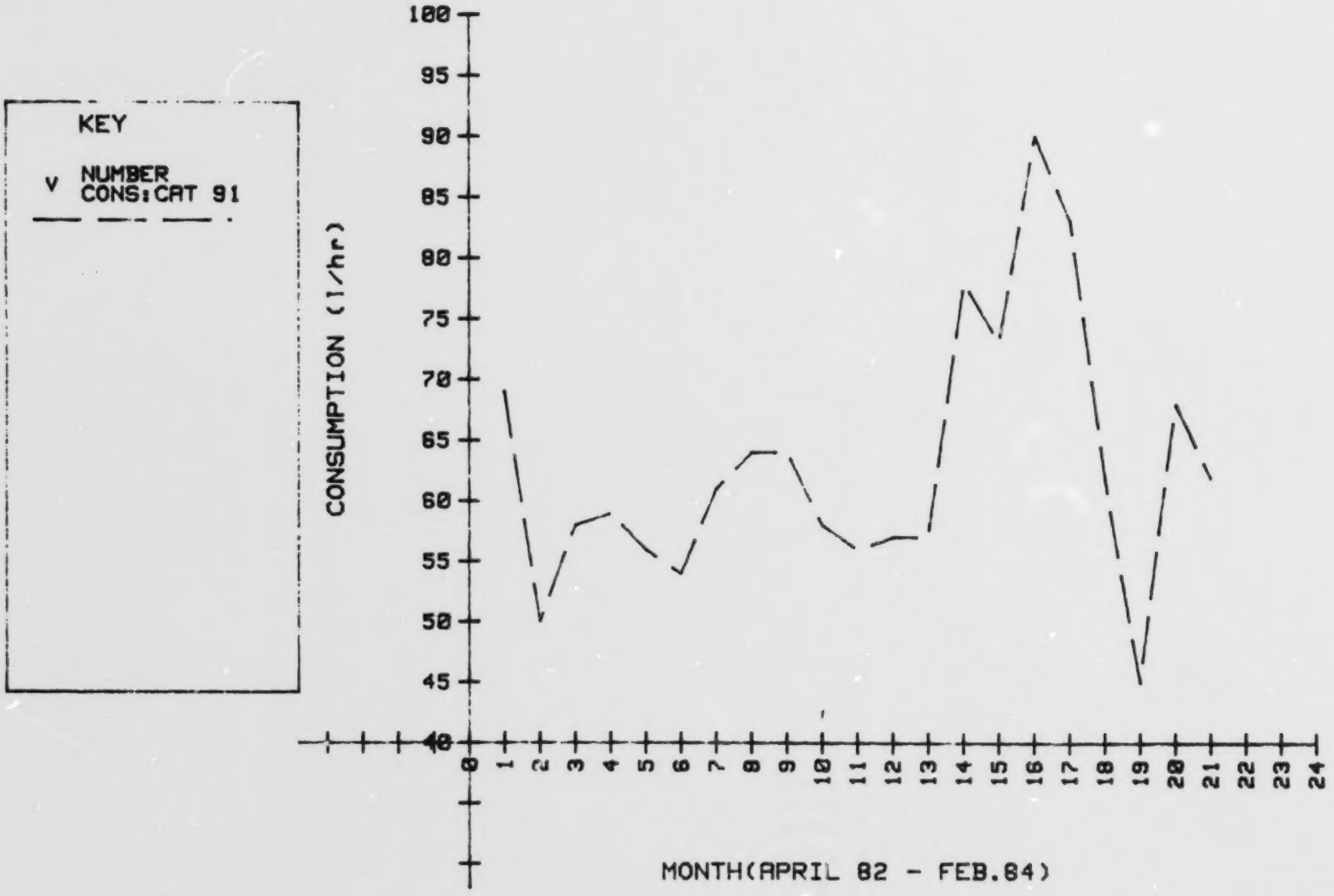



Fig. 4 - FUEL CONSUMPTION GRAPH
HIGHVALE MINE

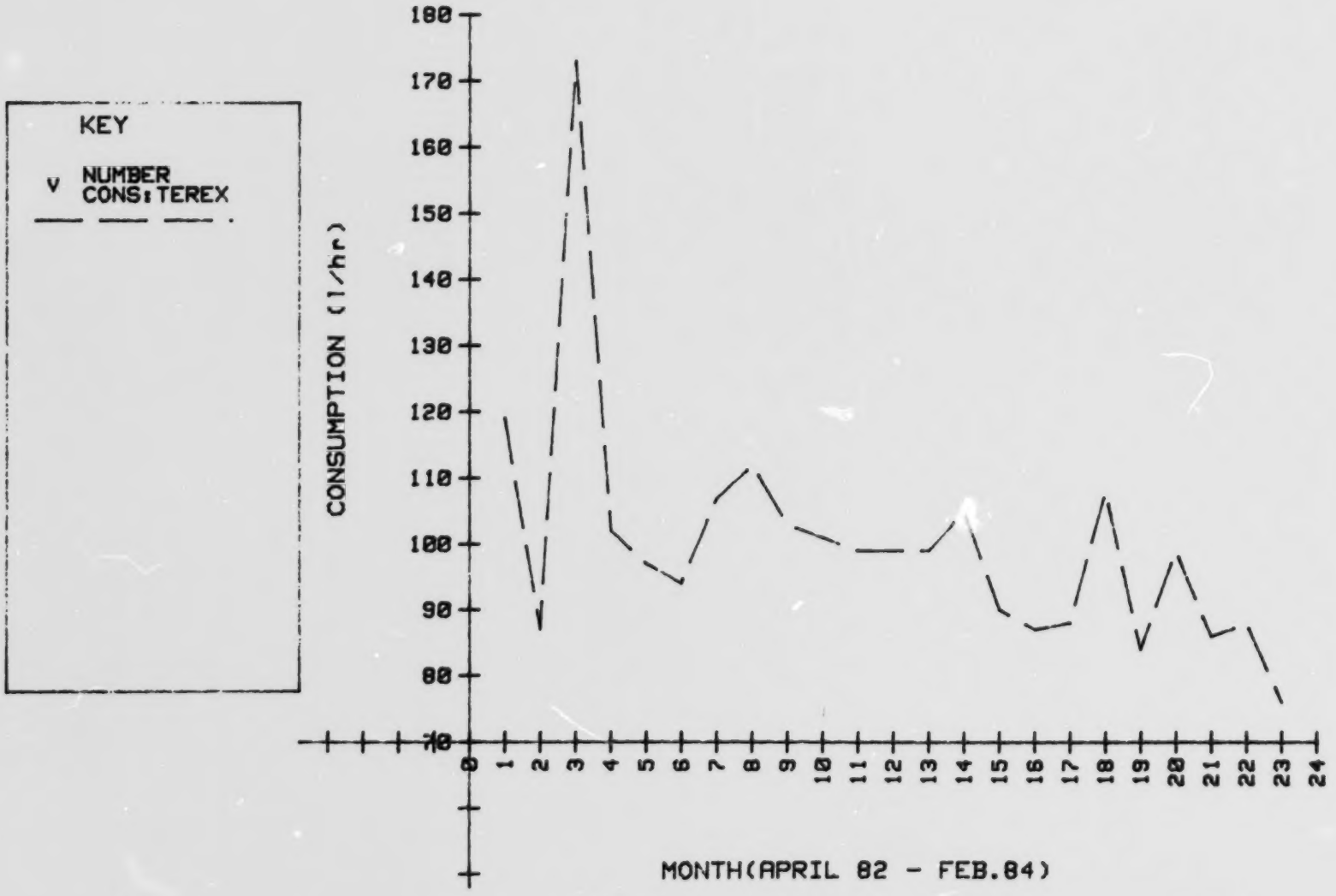



Fig. 5 - FUEL CONSUMPTION GRAPH
HIGHVALE MINE

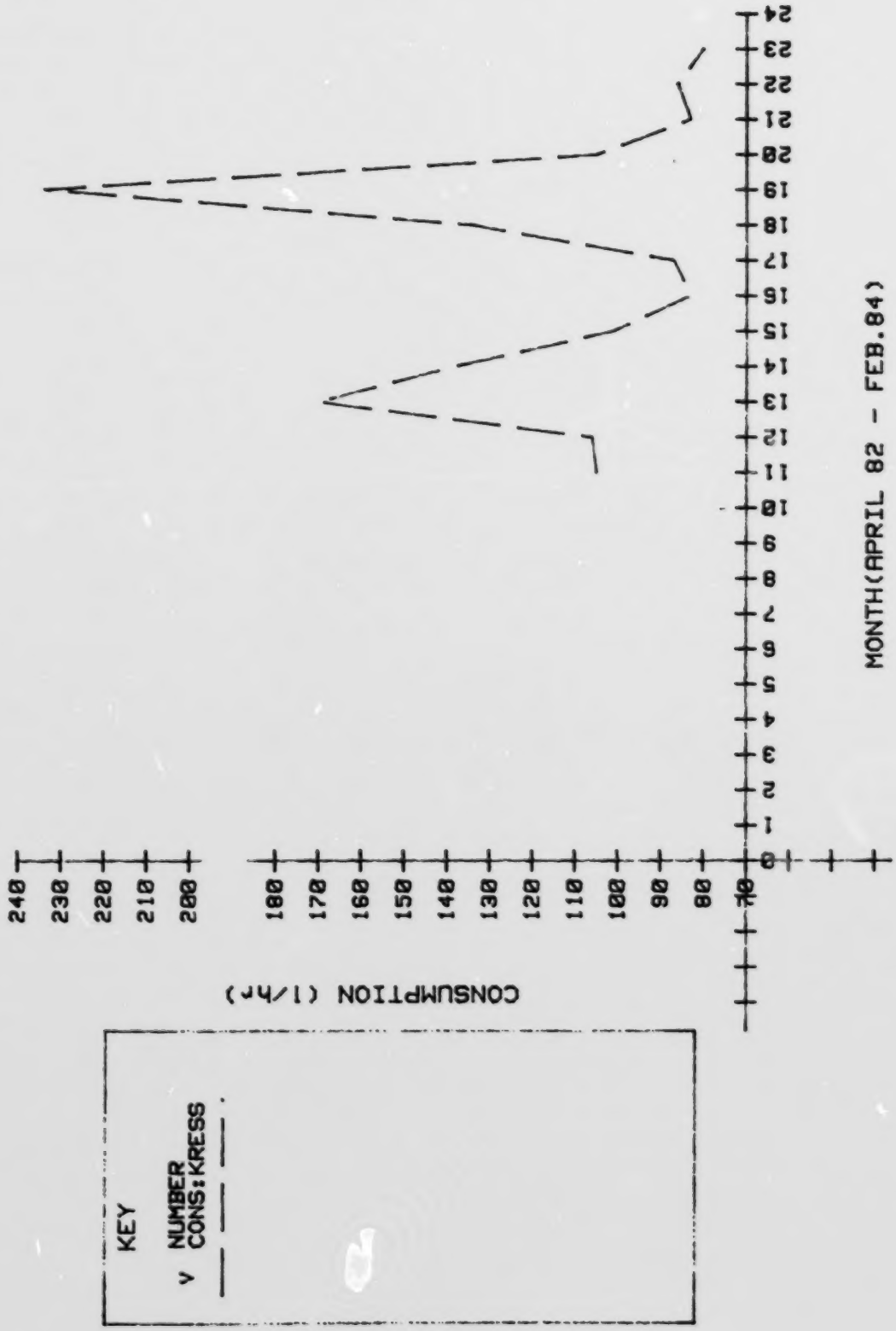



Fig. 6 - FUEL CONSUMPTION GRAPH
HIGHVALE MINE

Using the last two years' data it is concluded, the fuel consumption increased during summer 1983 for Euclid 77T trucks (ash haulers), Euclid 91T and Cat 91T trucks (coal haulers). The fuel consumption for Terex trucks was on steady decline during the survey.

## 3. CONCLUSIONS

The time study of the truck/shovel operation at the Highvale Mine in Alberta was initiated to obtain data for the validation of the computer model of truck/shovel mining operations under development at the National Research Council in Ottawa.

The collected data will be used to validate the steady state part of the model. The data on mining practices and information obtained by close contact with the operating personnel and through direct observation of the operating practices, will be used to specify dynamic event based models of the truck/shovel system.

In this study various travel times for different trucks running loaded or empty around the mine, are summarized. It is concluded that the new Kress 145T trucks are superior vehicles, and are best suited for the Highvale mining operation. The Cat 772 tractor units were observed to be the slowest (later on these units were rebuilt and are presently used as the water haulers). The travel speed for loaded trucks was in the range of 29 to 51 km/hr, and 45 to 67 km/hr for the empty trucks. The average dumping time was from 19 to 27 seconds at the Sundance dump, and from 21 to 25 seconds at the Keephills dump. The durations of the stay of trucks were in the Pits or around the tiple areas are also summarized for calculation of the maneuvering times needed for the loading or dumping. The TKPH values were evaluated to calculate possible truck tire overheating. It is concluded, that most tires of the coal haulers are subject to partial overheating. An attempt was made to use the collected time data to establish productivity changes during the 12 hour shift. It is concluded, that the Euclid 91T and Terex 136T tend to be slower during the second third of the shift, Euclid 91T were improving during the last third of the working shift. The fuel consumption was highest for Euclid 91T trucks, lowest for Euclid 77T ash haulers.

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